Analog Electronics lab session

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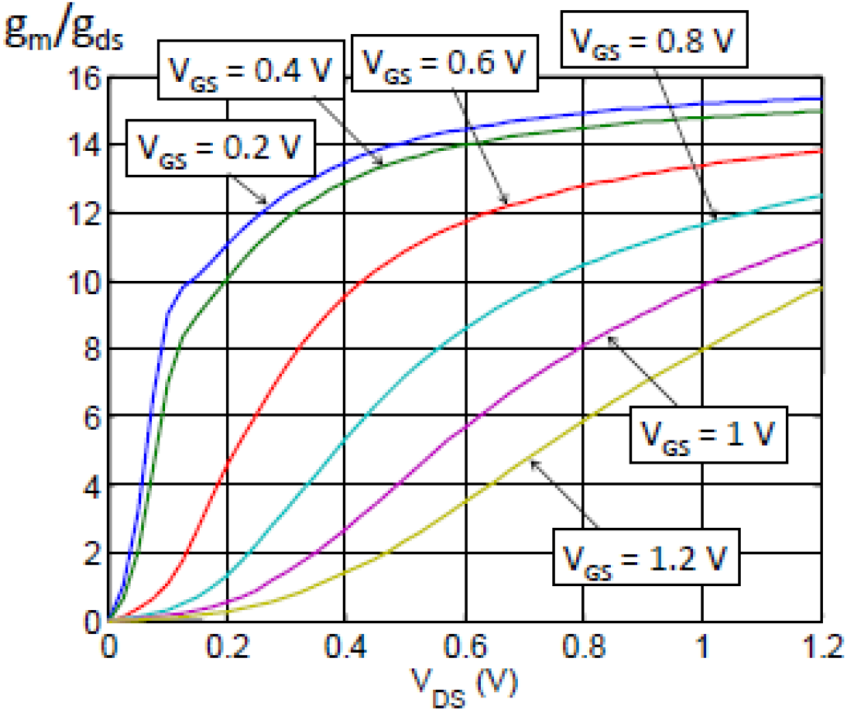
Summary

- Session 2:
  - Cascade of common source amplifier stages
  - The two-stage amplifier with Miller compensation

Building some intuition

- Do exercise 1
    - ETA: 10 minutes

EXERCISE 1-A



- For the high gain, the transistor should operate in the weak inversion (VGS=0.2V).
- The VDS needs to be increased in order to lower gds (VDS=1.2V).
- According to curves, the highest gain we can get is around 15V/V.

EXERCISE 1-B

$$f_T = \frac{g_m}{2\pi * (C_{gs} + C_{gd})}$$

- For the highest speed, VOV should be the largest, so VGS=1.2 V.
- In this case to get the highest gain, VDS=1.2 V.
- In conclusion, the result is 10 V/V.

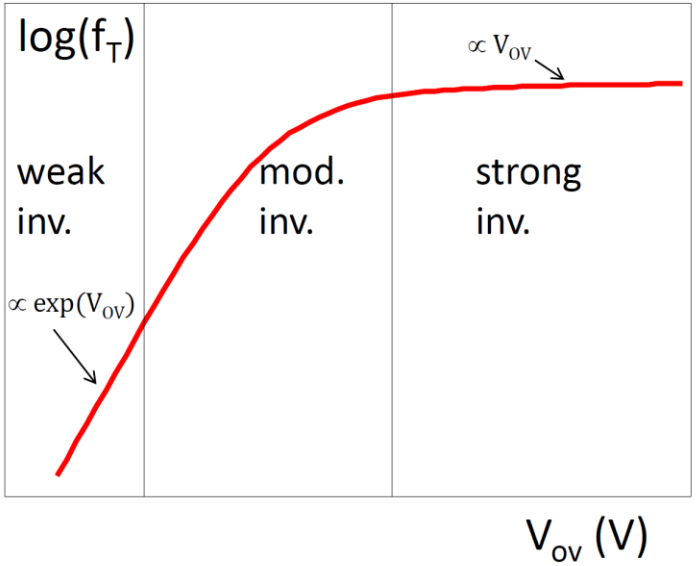
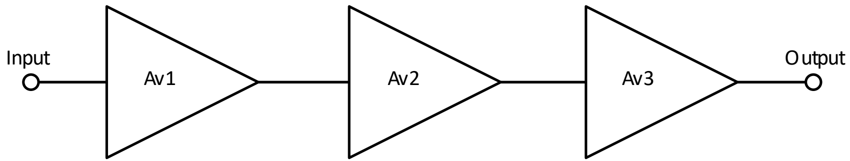


Figure 1.42: Dependence of f_T on the overdrive voltage.

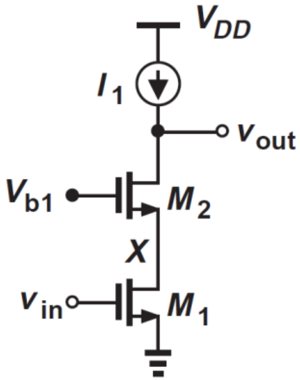
EXERCISE 1-C

- Cascade



- $The\ total\ gain = A_{v1} * A_{v2} * A_{v3}$

- Cascode



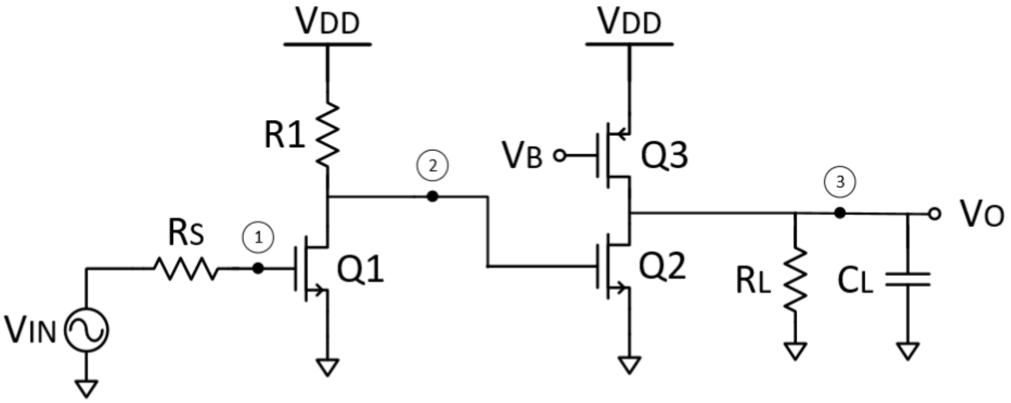
- $The\ gain = -\frac{g_{m1} * g_{m2}}{g_{ds1} * g_{ds2}}$

Building some intuition

- Do exercise 2
  - ETA: 25 minutes

EXERCISE 2-A

Finding the Total Gain



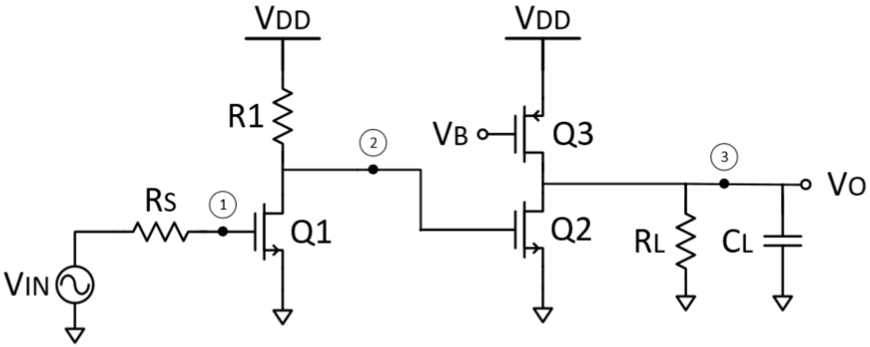
- Gain$= \frac{V_0}{V_{in}} = \frac{I_0}{V_{in}} * \frac{V_0}{I_0} = G_m * R_{out}$

- $A_{v1} = -g_{m1} * R_1 = -2mS * 5k\Omega = -10V/V$
- $A_{v2} = -g_{m2} * R_L = -20mS * 500\Omega = -10V/V$
- $A_v = A_{v1} * A_{v2} = 100\, V/V = 40dB$

EXERCISE 2-B

Finding Pole Frequencies

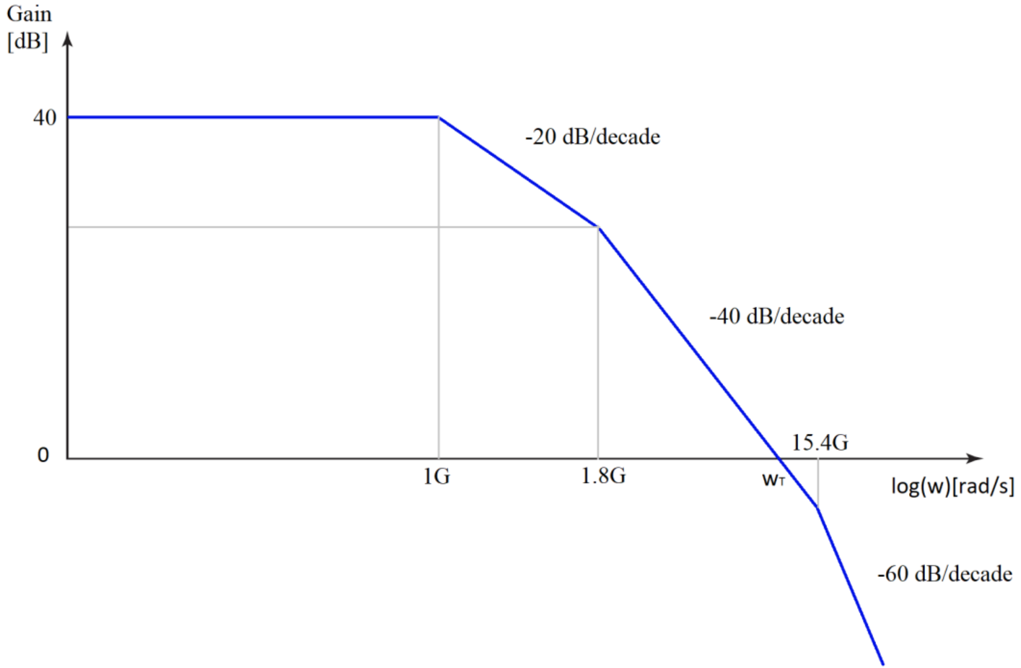
- $$pole\ frequency\ at\ node\ n\ in\ rad/s = \frac{1}{Total\ resistance\ between\ node\ n\ and\ AC\ ground} * \frac{1}{Total\ capacitance\ between\ node\ n\ and\ AC\ ground}$$



- $$\omega_{p1} = \frac{1}{R_S*(C_{gs1}+C_{gd1}*(1+g_{m1}*R_1))} = \frac{1}{500\Omega*130fF} = 15.4G\ rad/s$$
- $$\omega_{p2} = \frac{1}{R_1*(C_{gs2}+C_{gd2}*(1+g_{m2}*R_L))} = \frac{1}{5k\Omega*195fF} = 1G\ rad/s$$
- $$\omega_{p3} = \frac{1}{R_L*C_L} = \frac{1}{500\Omega*1.1pF} = 1.8G\ rad/s$$

EXERCISE 2-C

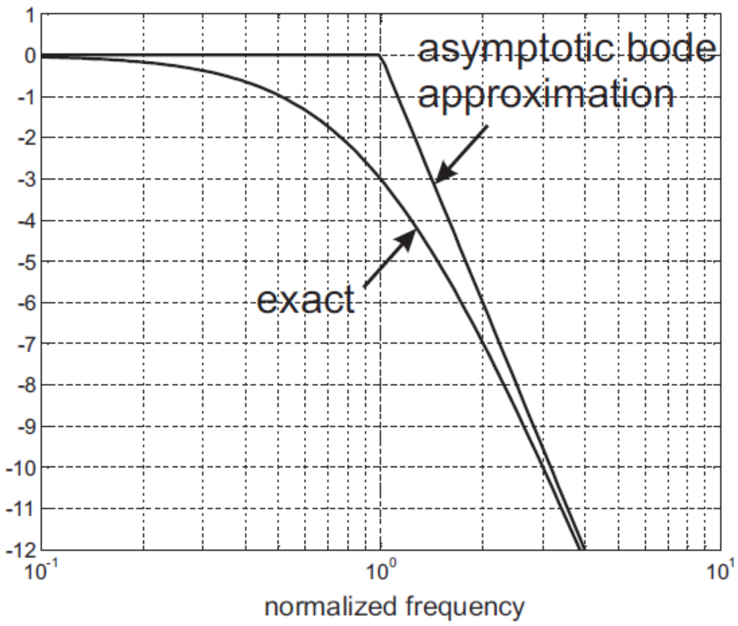
Finding ω_T Value



- $40 - 20 * \log\left(\frac{1.8G\ rad/s}{1Grad/s}\right) = 34.9dB$
- $34.9 - 40 * \log\left(\frac{\omega_T}{1.8Grad/s}\right) = 0dB$
- $\omega_T = 13.4G$ rad/s

EXERCISE 2-C

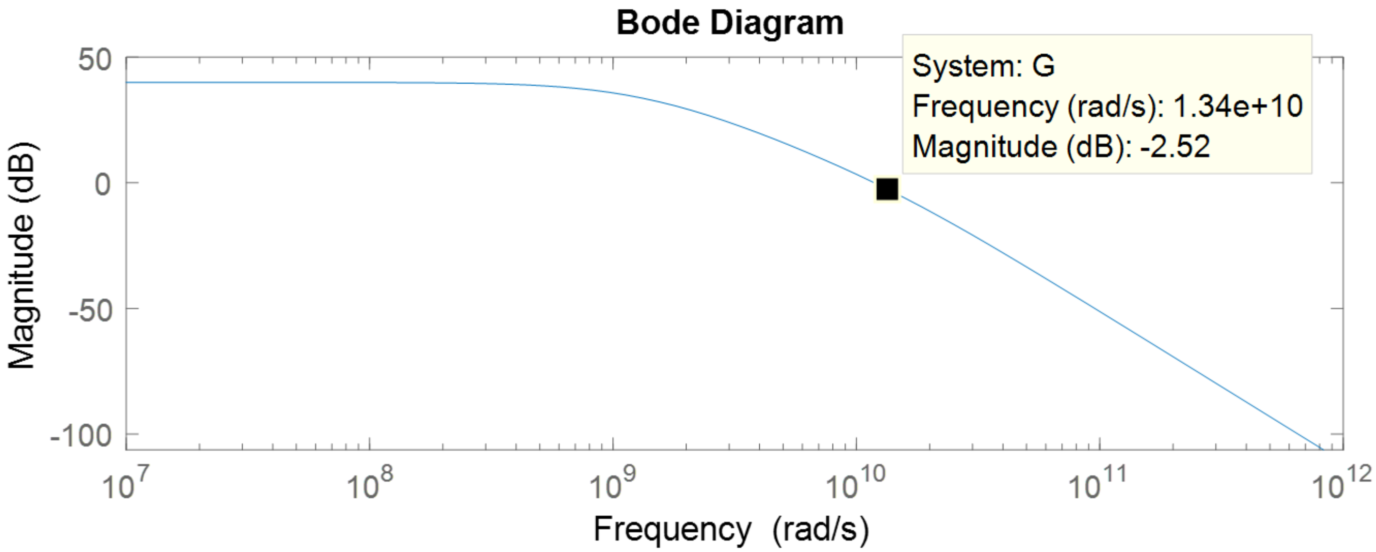
Asymptotic Bode Approximation vs Exact Curve



EXERCISE 2-C

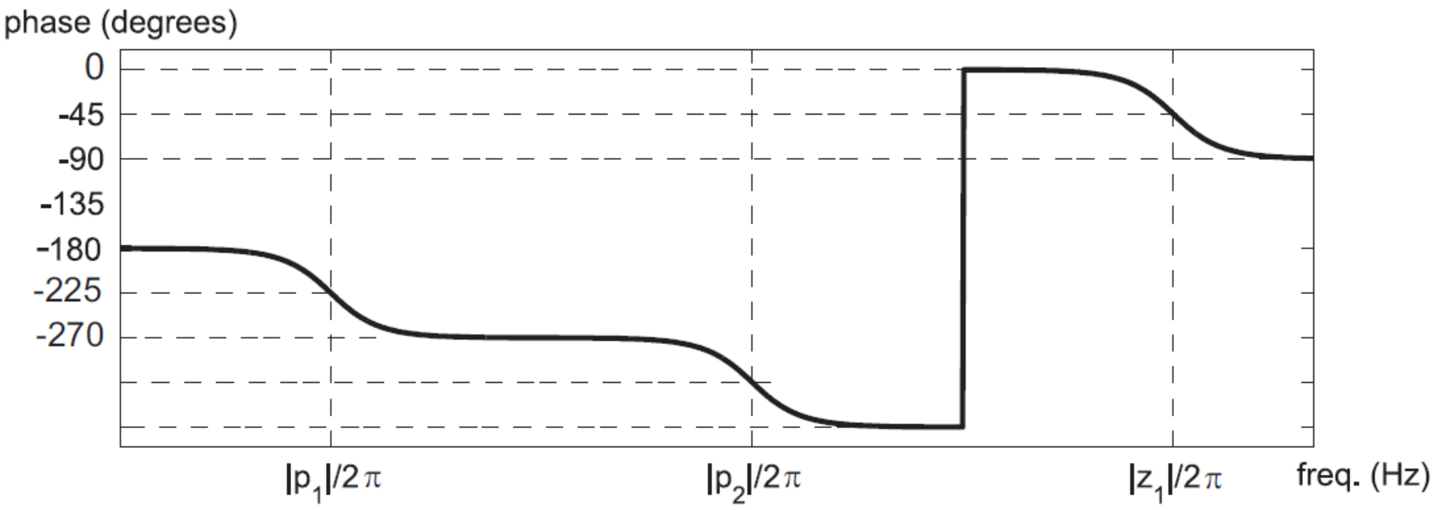
MATLAB Magnitude Plot

- Calculated $\omega_T = 13.4G\ rad/s$



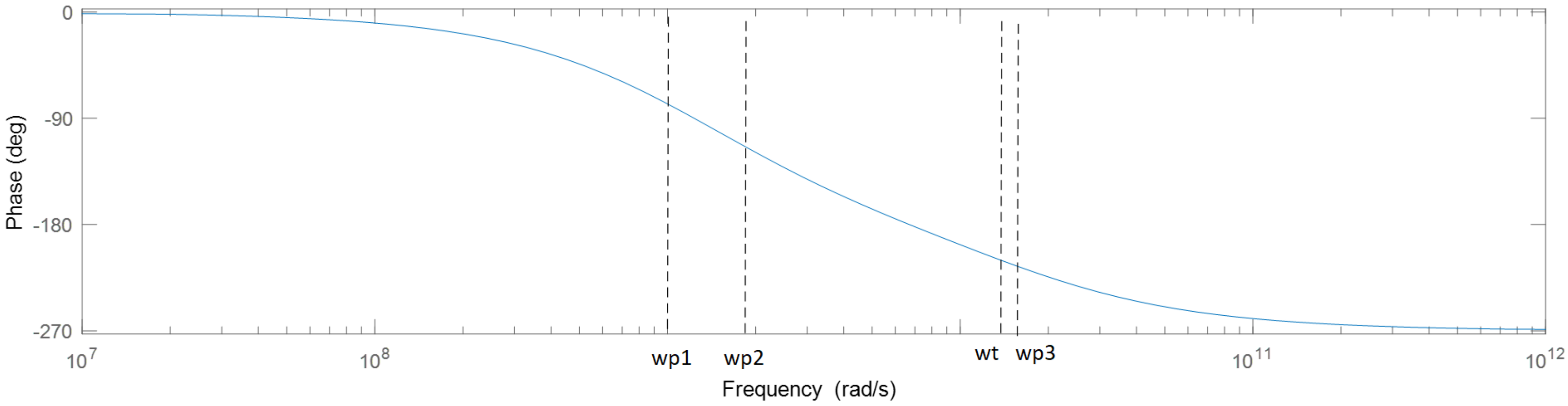
EXERCISE 2-C

Phase Shift due to Poles and Zeros



EXERCISE 2-C

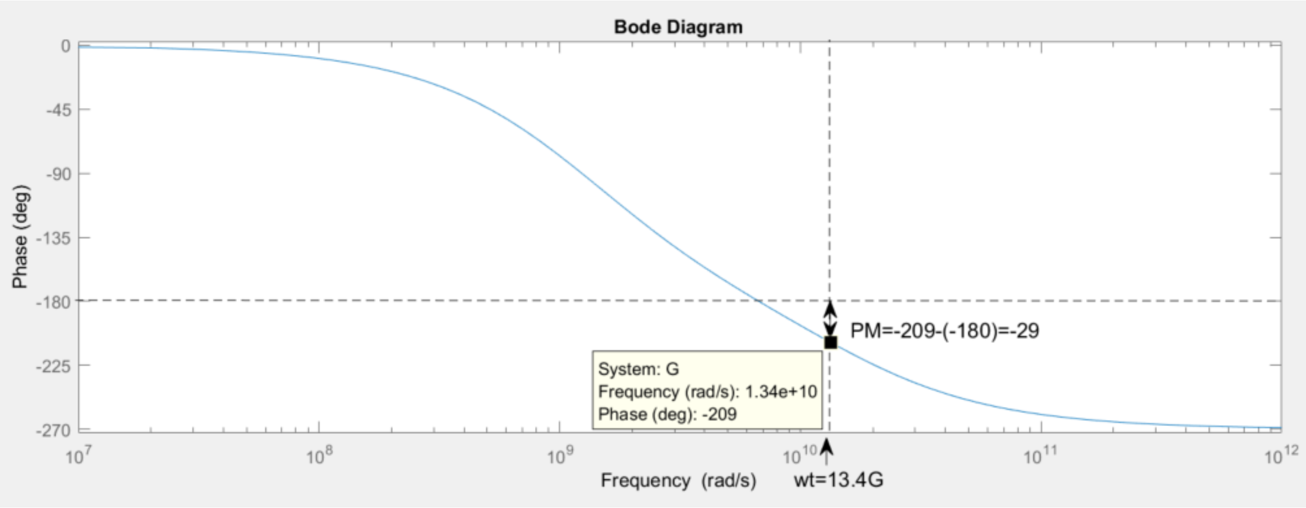
MATLAB Phase Plot



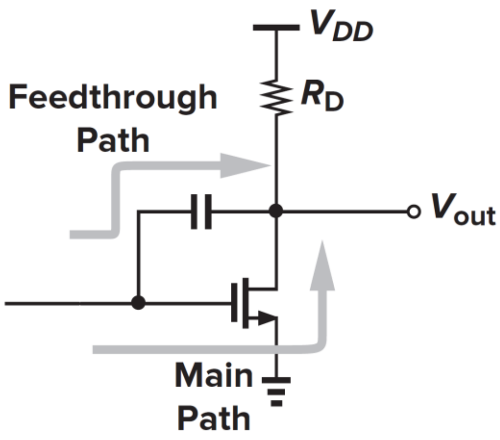
EXERCISE 2-C

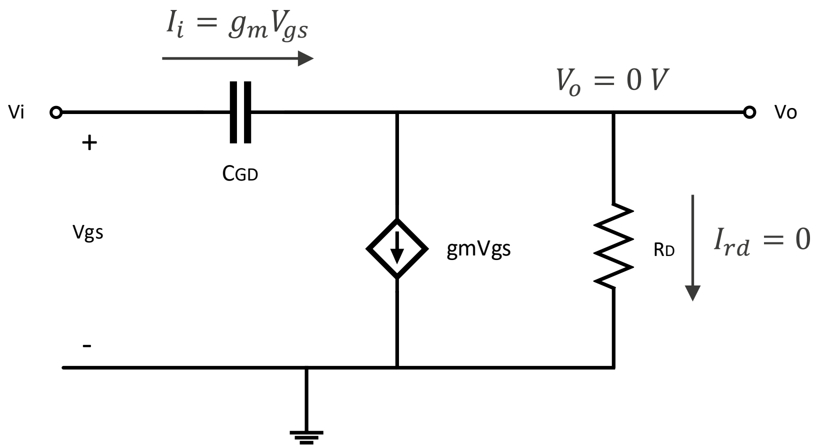
Finding Phase Margin

- $Total\ phase\ shift = 0 - tan^{-1}\frac{13.4Grad/s}{1Grad/s} - tan^{-1}\frac{13.4Grad/s}{1.8Grad/s} - tan^{-1}\frac{13.4Grad/s}{15.4Grad/s} = -209.1^o$
- $Phase\ margin = -209.1^o - (-180^o) = -29.1^o$



DERIVING REAL ZEROS





- $$\frac{V_i}{1/(s_z * C_{GD})} = g_m * V_i$$
- $$s_z = \frac{g_m}{C_{GD}}$$

Building some intuition

- Do exercise 3
    - ETA: 25 minutes

EXERCISE 3-A

Dependence of Poles on C_{gd} value

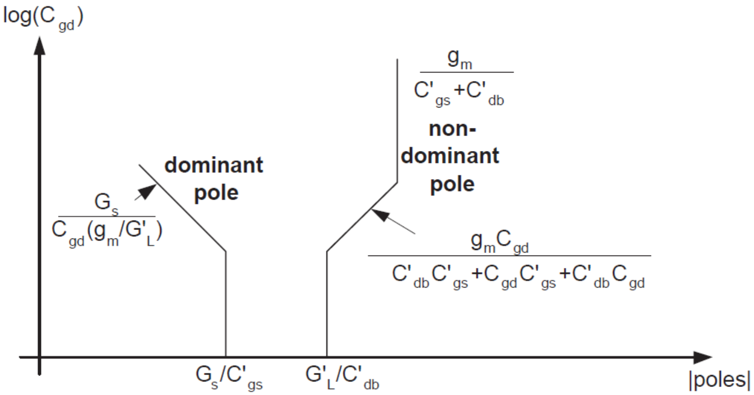
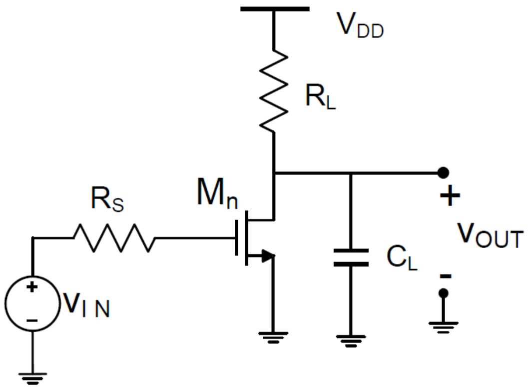


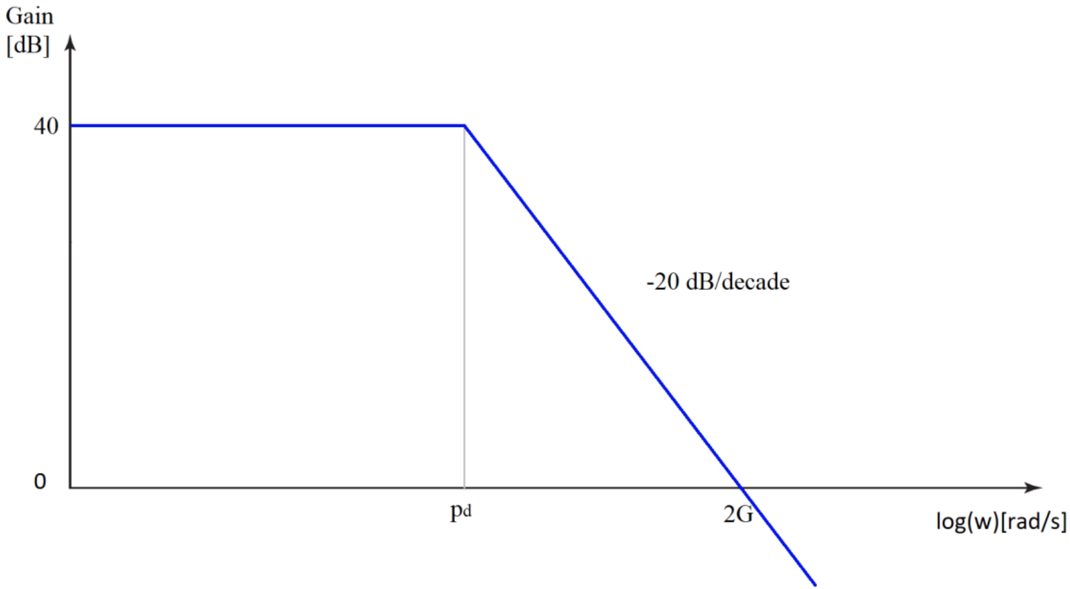
Figure 2.15: Bode diagram of pole splitting: asymptotes indicate the position of poles as a function of C_{gd} on a log-log *scale.*



- $C'_{gs} = C_{gs} + C_{gb}$
- $C'_{db} = C_{db} + C_L$
- $G'_L = g_{ds} + G_L$

EXERCISE 3-A

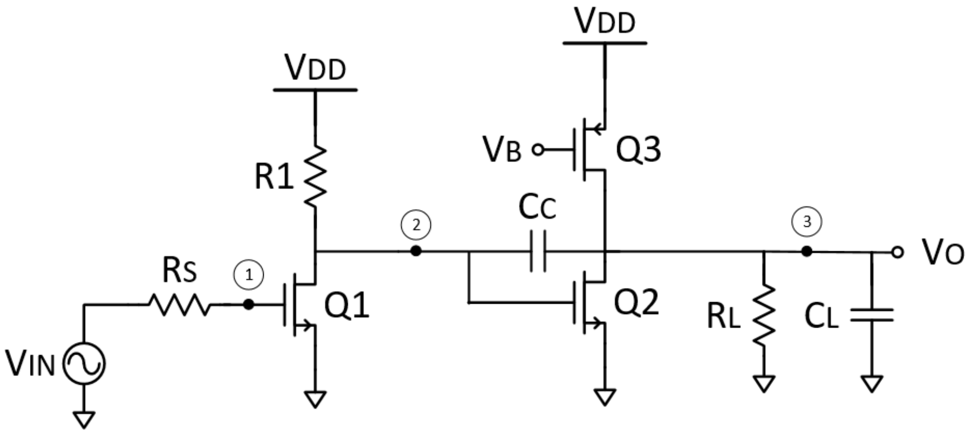
Finding the Value of C_c



- $\omega_T = GBW = |A_v * p_d|$
- $A_v = g_{m1} * R_1 * g_{m2} * R_L$
- $p_d = \frac{-1}{R_1 * (C_c * g_{m2} * R_L)}$
- $\omega_T = GBW = |A_v * p_d| = \frac{g_{m1}}{C_c}$
- $\omega_T = 2Grad/s = \frac{2mS}{C_c}$
- $C_c = 1pF$

EXERCISE 3-B

Finding Pole Frequencies

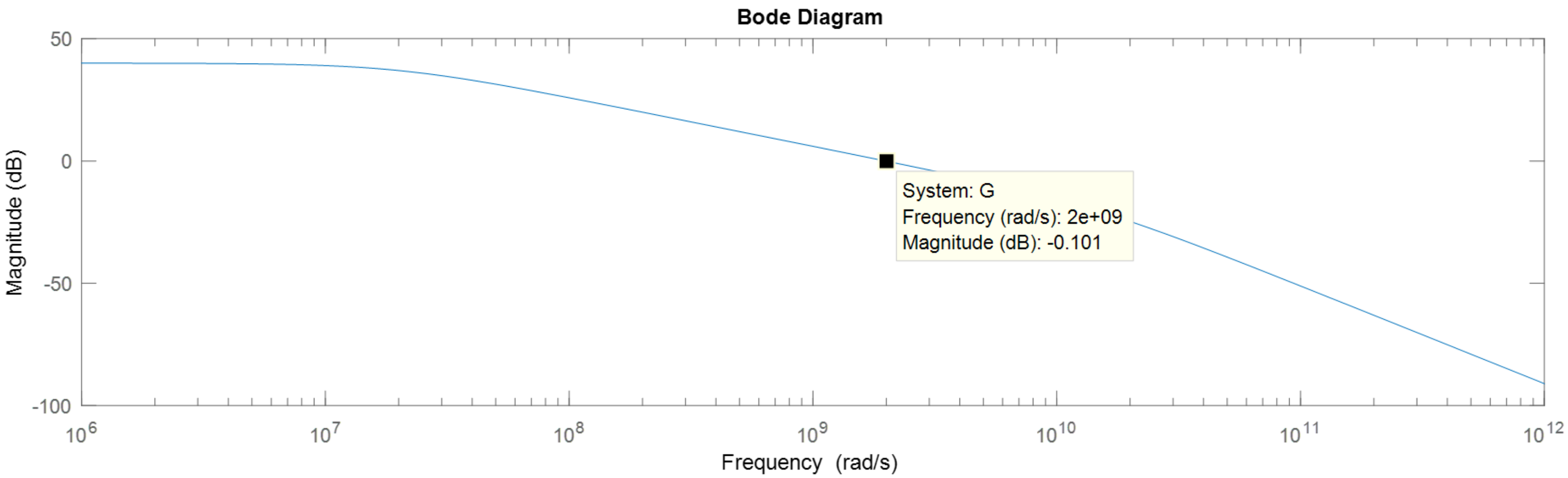


- $\omega_{p1} = \frac{1}{R_S*(C_{gs1}+C_{gd1}*(1+g_{m1}*R_1))} = \frac{1}{500\Omega*130fF} = 15.4G\ rad/s$
- $\omega_{p2} = \frac{1}{R_1*(C_c*g_{m2}*R_L)} = \frac{1}{5k\Omega*20mS*500\Omega*1pF} = 20M\ rad/s$
- $\omega_{p3} = \frac{g_{m2}}{C_L} = \frac{20mS}{1.1pF} = 18.2G\ rad/s$
- $\omega_{z1} = \frac{g_{m2}}{C_c} = \frac{20mS}{1pF} = 20G\ rad/s$

EXERCISE 3-B

MATLAB Magnitude Plot

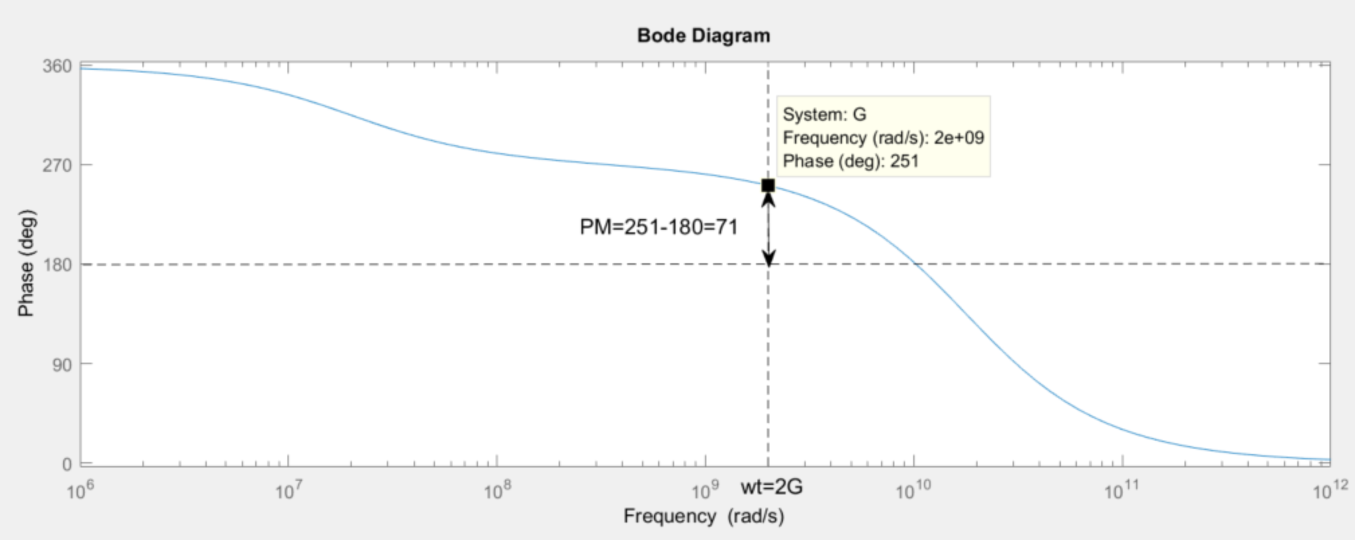
- Calculated $\omega_T = 2G\ rad/s$



EXERCISE 3-B

Finding Phase Margin

- $Total\ phase\ shift = 0 - tan^{-1}\frac{2Grad/s}{20Mrad/s} - tan^{-1}\frac{2Grad/s}{15.4Grad/s} - tan^{-1}\frac{2Grad/s}{18.2Grad/s} - tan^{-1}\frac{2Grad/s}{20Grad/s} = -108.8^o$
- $Phase\ margin = -108.8^o - (-180^o) = 71.2^o$

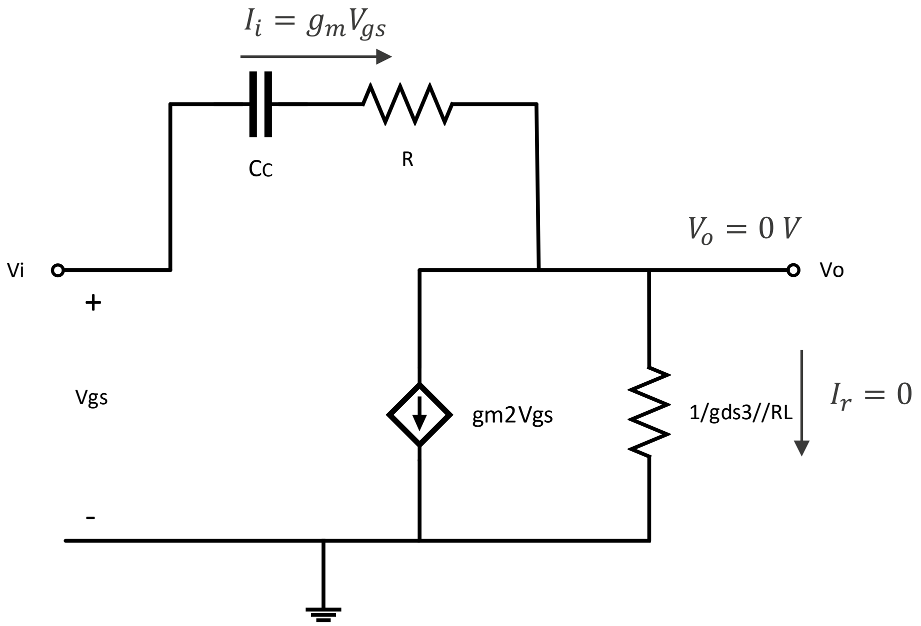


Building some intuition

- Do exercise 4
  - ETA: 15 minutes

EXERCISE 4-A

Expression of the Zero After Adding the Resistor



- $$\frac{V_i}{R + \frac{1}{s_Z * C_C}} = g_{m2} * V_i$$
- $$s_Z = \frac{1}{C_C * (\frac{1}{g_{m2}} - R)}$$

EXERCISE 4-A

Finding Value of R

- $\omega_{z1} = \omega_{p1} = 15.4 Grad/s = \left| \frac{1}{C_c * \left(\frac{1}{g_{m2}} - R \right)} \right|$
- $R = 64.9\Omega$

EXERCISE 4-B

Finding Phase Margin

- $Total\ phase\ shift = 0 - tan^{-1}\frac{2Grad/s}{20Mrad/s} - tan^{-1}\frac{2Grad/s}{18.2Grad/s} = -95.7^{o}$
- $Phase\ margin = -95.7^{o} - (-180^{o}) = 84.3^{o}$

FINAL REMARK

$|p_2|/GBW_T$ vs Phase Margin in Two-poles System

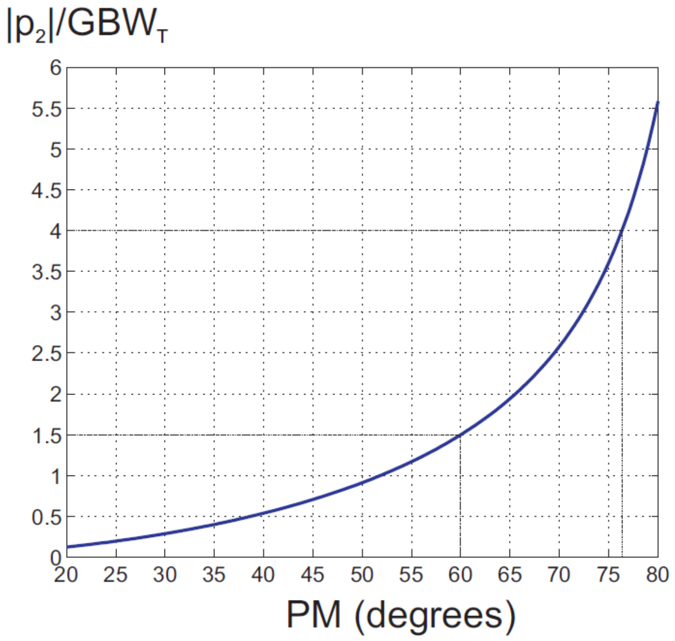


Figure 7.3: Relation between the phase margin and the ratio of the second pole and GBW_T.

imec

embracing a better life